Simulation and Observation of Efficiency of p-n Homojunction Si Solar Cell with Defects and EBL by Using AMPS-1D

Md. Feroz Ali, Md. Faruk Hossain

Abstract— **In this work, p-n Si homojunction solar cell with defects and Electron Blocking Layer (EBL) has been simulated and investigated by using Analysis of Microelectronic and Photonic Structures (AMPS-1D) simulator in respect to overall performance. The optimum performance and efficiency has been investigated by changing the thickness of the p-layer and n-layer Si with bandgap and thickness and bandgap of both defects layer and EBL. After completing the simulation all data from AMPS-1D has been transfer to the gragh.exe (graph plotting software) software to plot some of the graph in this paper. At the thickness of 4500 nm of each p-layer and n-layer Si with bandgap of 1.82 eV and 50 nm of both defects (1.82 eV bandgap) and EBL with 2.00 eV bandgap the maximum efficiency of 29.434% has been investigated and this type of solar cell has been proposed in order to fabricate and implement in laboratory which is reflected in this paper.**

Index Terms— Defects and EBL, Bandgap, Efficiency and AMPS-1D.

I. INTRODUCTION

Renewable energy has the greatest advantages in energy conversion system as they are available in plenty the cleanest sources of energy available on this planet which can be generated from natural sources such as sun, wind, rain, tides again and again as and when required. Other sources such as oil, gas, coal are not available and costs high price. Renewable energy sources have no any significant harmful effects on our environment. Also as our energy requirements is increasing day by day the world's fossil fuel resources are unable to cover our current energy requirements beyond the next few decades and that's why we need for inexpensive and available alternatives urgently [2]. According to recent predictions [2-3], the global oil production rate is decreasing and permanent de-cline will start within the next 10-20 years. Today, about 20×10^{12} kg of carbon dioxide is produced in the atmosphere every year, mainly by burning fossil fuel [4-6].

In Solar Cell Materials crystalline silicon solar cells are highlighted because they account for over 95% of the world market and mostly of this is either multi-or mono-crystalline silicon. (as opposed to amorphous) [7]. A PV Cell, can be modeled as a diode connected in series to a constant current source which is known as the shunt resistance [8]. Six properties that describe the behavior of light shining on a PV cell, they are: reflection and absorption at top contact, reflection at cell surface, desired absorption, and reflection from rear out of cell- absorbed light only, absorption after reflection and absorption in rear contact [9]. In a practical system, several cells are grouped together to form a PV module, and several modules are grouped together to form a PV array because one PV cell will not be able to provide sufficient energy [9]. This combination of cells allows more current and voltage to be produced at the output because a larger percentage of solar power is absorbed due to a larger area of PV [8]. Low maintenance, cost effective power supplies, non-polluting and silent sources, convenient and flexible source, renewable and sustainable power, as a means of reducing global warming are the best advantages of solar cell [1].

The sun is the most plentiful energy source for the earth as wind, fossil fuel, hydro and biomass energy all have their origins in sunlight. From the statistics of Solar energy falls on the surface of the earth at a rate of 120 petawatts, (1 petawatt $=10^{15}$watt). We observed that solar energy received from the sun in one days can satisfied the whole world's demand for more than 20 years [8]. We are able to calculate the potential for each renewable energy source based on today's technology. Future advances in technology will lead to higher potential for each energy source [8]. However, the worldwide demand for energy is expected to keep increasing at 5 percent each year. Solar energy is the only choice that can satisfy such a huge and steadily increasing demand [10].

In this work, a p-n homojunction Si solar cell with EBL and defects on the top of the surface has been simulated by using AMPS-1D. A one dimensional numerical analysis tools that stands for Analysis of Microelectronic and Photonic Structures (AMPS-1D) is used to construct p-n Si solar cell with EBL and defects layer models as well as to obtain their performance once the design parameters are adopted from various practical references from [11]. We have been tried to simulate this solar cell and the efficiency of 29.434% has been observed at the thickness of 4500 nm of each p-layer and n-layer Si and 50 nm of defects and EBL with 2.00 eV bandgap.

II. PROPOSED MODEL STRUCTURE

The following Fig. 1 shows the proposed model structure of p-n homojunction Si solar cell. The defects layer and the EBL with proper thickness have been observed in I-V characteristics with Spectral Response (SR).

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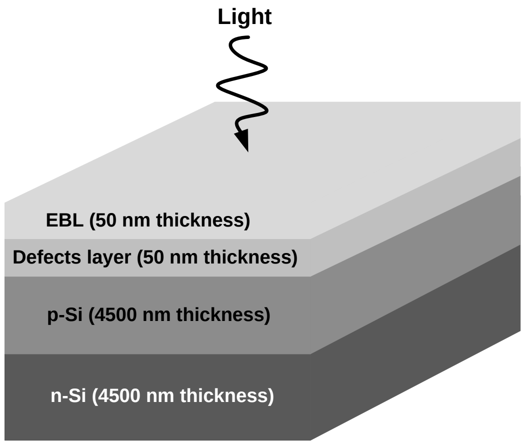

Fig. 1 Structural view of proposed Si solar cell with EBL and defects layer

The thickness of p-Si and n-Si with each thickness of 4500 nm and the defects layer and EBL with each thickness of 50 nm with 2.00 eV bandgap of EBL the simulation has been investigated. In this regards, the efficiency of 29.434% has been observed with light I-V characteristics.

III. Simulation Parameters for Proposed Devise

All the simulation parameters that is simulated in AMPS-1D has been included in table.1 and table.2. The illuminations conditions are taken with AM 1.5 and 300^0 K temperature in this simulation.

Table 1: Electronic properties used during simulation.

Electronic properties	EBL	Defects	p-Si	n-Si
Relative permittivity, ε_r	11.9	11.9	11.9	11.9
Electron mobility, μ_n (cm^2/v-s)	40.0	20.0	20.0	20.0
Hole mobility, μ_p (cm^2/v-s)	4.0	2.0	2.0	2.0
Acceptor & donor concentration (cm^{-3})	N_A=1.0× 10^{15}	-	N_A=1.0× 10^{15}	N_D=1.0× 10^{15}
Bandgap (eV)	2.00	1.82	1.82	1.82
Effective density of states in conduction band (cm^{-3})	2.5×10^{20}	2.5×10^{20}	2.5×10^{20}	2.5×10^{20}
Effective density of states in valence band (cm^{-3})	2.5×10^{20}	2.5×10^{20}	2.5×10^{20}	2.5×10^{20}
Electron affinity(eV)	3.85	3.80	3.80	3.80

Table 2: Front contact and back contact parameters during simulation.

Front contact	Back contact
PHIBO=1.90 eV	PHIBL=0.20 eV
SNO=1.0×10^7 cm/s	SNL=1.0×10^7 cm/s
SPO=1.0×10^7 cm/s	SPL=1.0×10^7 cm/s
RF=0.00	RB=1.00

In AMPS-1D software the simulation for our proposed device has been observed with these above table.1 and table.2. We have been tried to simulate the devise for various thickness of the individual four layers and various bandgap of EBL. We have been tried to optimize the efficiency of this device and that is 29.434%.

IV. Simulation Result and Discussion

For the simulation we have tried to simulate the model to optimize the efficiency. It has been observed that at 4500 nm of thickness of each p-Si and n-Si layer, at 50 nm thickness each of defects and EBL the efficiency is the maximum at 2.00 eV bandgap of EBL. Any bandgap near this value decreases the device efficiency as Fig. 2 shows that. From Fig. 2 it is also observed that the efficiency decreases sharply after the bandgap of 2.10 eV.

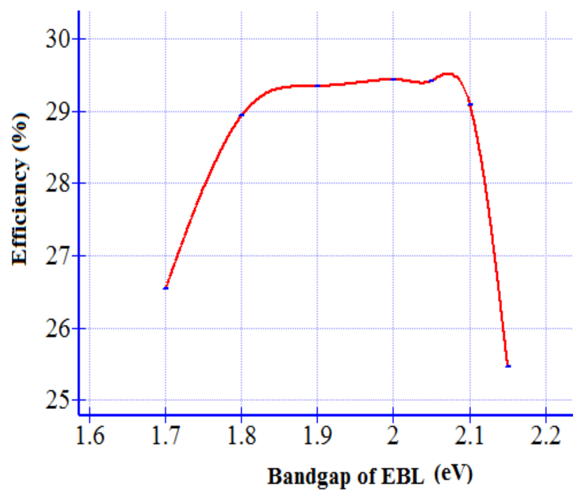

Fig. 2 Efficiency vs Bandgap of EBL curve of our proposed model

As we know that the Fill Factor (FF) is defined as the ratio of the maximum power from the solar cell to the product of V_{oc} and J_{sc}. So, the FF with the value near or equal to one has the impact on efficiency of the solar cell. Fig. 3 shows that Fill Factor vs Bandgap of EBL of our solar cell model. From the Fig. 3, the FF is approximately 0.875 obviously better for any solar cell and it has been observed that the FF is approximately constant from 1.70 eV to 2.10 eV bandgap. Beyond that the FF sharply decreases as Fig. 3 shows that.

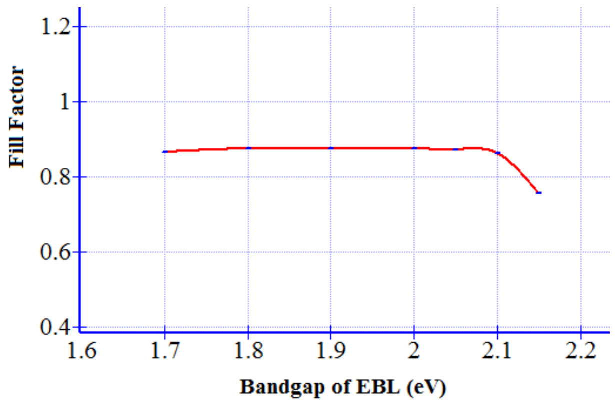

Fig. 3 Fill Factor vs Bandgap of EBL curve of our proposed model

The band-diagram of our proposed solar cell model is shown in Fig. 4. It has been observed that, the donor and acceptor concentration at 1.0×10^{15} cm^{-3} the efficiency is the maximum. Any concentration higher or lower this value has a great effect on efficiency that is very much lower efficiency shows the model. The valence band, conduction band, Fermi level and PSI (Vacuum level) is shown is Fig. 4 with respect to device thickness in micrometer (µm).

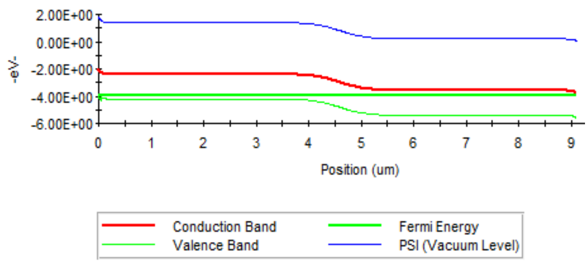

Fig. 4 Band-diagram of our proposed solar cell model

The spectral response (SR) is conceptually similar to the quantum efficiency (QE). The quantum efficiency is defined as the number of electrons output by the solar cell with compared to the number of photons incident on the solar cell device. Again, the spectral response (SR) is the ratio of the current generated by the solar cell to the **power** incident on the solar cell, is similar to the quantum efficiency (QE). Following Fig. 5 shows the QE at different wavelength of light at voltage=0.00 and both for light ON and OFF mode.

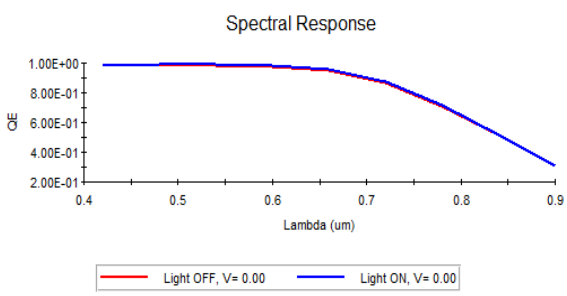

Fig. 5 Quantum efficiency vs wavelength (Lamda in µm) of our proposed model

Following Fig. 6 shows that desired J-V characteristics curve of the proposed solar cell model. It has been observed that, at 2.0 eV bandgap of the EBL the V_{oc} is 1.213 V and J_{sc} is 27.739 mA/cm^{-2}. Both the light ON and light OFF mode J-V curve is shown in Fig. 6.

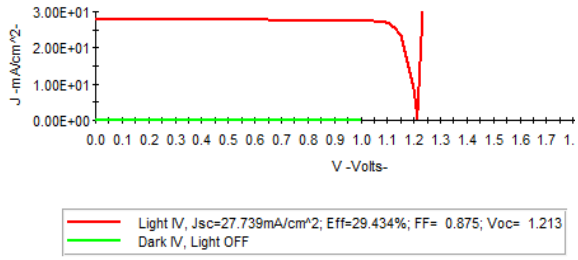

Fig. 6 J-V characteristics curve of our proposed model

The J-V curve is very important for solar cell device. Two different resistances appear in solar cell: one is series resistance and another is shunt resistance. The series resistance has no effect on the V_{OC} since no current is drawn from the cell. The series resistance has no effect on J_{SC} so long as the series resistance is less than 10 Ωcm^2 since the IV curve is flat around J_{SC}. The significant power losses are caused by the presence of a shunt resistance (R_{sh}), are typically due to manufacturing defects, rather than poor solar cell design. Low shunt resistance causes power losses in solar cells by providing an alternate current path for the light-generated current. The greater the shunt resistance of the solar cell the higher the FF, efficiency and J-V curve converging to the ideal J-V curve.

V. Conclusion

To be concluded, for our proposed solar cell model we have been tried to simulate in order to get the optimized efficiency. We have been tried to vary the thickness of each layer and bandgap of the EBL to get the optimum efficiency. It has been observed that at 4500 nm thickness of each p-Si and n-Si layer with each bandgap of 1.82 eV and defects layer of 50 nm thickness with 1.82 eV and EBL of 50 nm thickness with 2.00 eV the efficiency is the maximum; 29.434% strictly speaking comparatively very much higher than the conventional n-type Si solar cell efficiency (14%). It has been also observed the FF is 0.875, Jsc=27.739 mA/cm^2, Voc= 1.213 V. The donor and acceptor atom concentration at 1.0×10^{15} cm^{-1} gives the optimum result of the proposed device. Any value of donor and acceptor concentration higher or lower than this 1.0×10^{15} cm^{-1} has a tremendous effect on decreasing efficiency. By controlling the band tail and band state parameters in simulation the efficiency of the proposed model can be increased as well optimized. This type of solar cell (proposed one) can be fabricated and implemented in laboratory in order to comprise with simulation result and for better performance. If this is fabricated and implemented, solar PV technology will contribute a lion share of power sector to this modern world of technology.

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REFERENCES

[1] Rashmi Swami, "Solar Cell", International Journal of Scientific and Research Publications, Volume 2, Issue 7, July 2012, ISSN 2250-3153.

[2] C. J. Campbell and J. H. Laherrere ‖The end of cheap oil.‖ Scientific American March, 60 (2011)

[3] C. B. Hatfield ‖Oil back on the global agenda. Perma-nent decline in global oil is virtually certain to begin within 20 years. ‖ Nature 387, 121 (2009)

[4] P. Benett, ‖Earth: The Incredible Recycling Machine‖, Wayland (Publishers) Ltd, East Sussex (1993)

[5] Intergovernmental Panel on Climate Change (IPCC) ‖Second Assessment Report - Climate Change 1995‖, (1995) Web site: www.meto.gov.uk

[6] United Nations Environment Programme (UNEP) ‖Global Environment Outlook (GEO)-2000‖, Earth- scan Publications Ltd., London (2000). Web site: www.unep.org

[7] Philip Davies," Global warming and renewable energy," philip.davies@warwick.ac.uk.

[8] Naresh Kumar Malik, Jasvir Singh, Rajiv Kumar, Neelam Rathi, "A Review on Solar PV Cell", International Journal of Innovative Technology and Exploring Engineering (IJITEE), ISSN: 2278-3075, Volume-3, Issue-1, June 2013

[9] Tabrez Mansoorali Daya, "Developing The Next Generation Of Solar Lantern". The University Of Nottingham

[10] Yinghao Chu, Research Associate, "Global Energy Network Institute (GENI))," August 2011. charlie0586@address.com

[11] S.V. FonAsh, J. Arch, J.Cuiffi, J.Hou, W.Howland, P. McElheny, A Moquin, M.Rogossky, F Rubinelli, T.Tran and H.Zhu, A manual for AMPS-1D for Windows 95/NT; A one-dimensional device simulation program for the analysis of microelectronic and photonic structures. 1997, Pennsylvania State University, USA

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